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ATTENUATION MEASUREMENTS OF EAR MUFFS AT LOCKERBY MINE 1984

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ELLIOT LAKE LABORATORY

JANUARY 1986

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24 pp

MINERAL AND ENERGY TECHNOLOGY
MINING RESEARCH LABORATORIES
DIVISION REPORT M&ET/MRL 86-59 (TR)

ATTENUATION MEASUREMENTS OF EAR MUFFS AT LOCKERBY MINE 1984

by

M.U. Savich* and J.K. Weglo**

ABSTRACT

Ear muffs are the main protection of the mining workforce for the attenuation of noise.

The measurement of head size as against clamping force as well as the condition of the ear muffs are demonstrated as important variables in the attenuation of noise.

The "NO NOISE" ear muff attenuation was about 12.5 dBA as an average with Standard Deviation of about 4 to 6 dBA depending on the use of the ISO or OSHA made at the Lockerby Mine.

The Mark V ear muffs, replacing those in the study, based on clamping force measurements versus head size can be expected to produce attenuation >14 dBA.

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MESURE DE L'EFFICACITÉ DES CASQUES ANTIBRUIT À ATTÉNUER LE BRUIT À LA MINE LOCKERBY 1984

par

M.U. Savich* et J.K. Weglo**

RÉSUMÉ

Les casques antibruit sont la principale source de protection contre le bruit pour les travailleurs miniers.

La mesure de la taille de la tête par rapport à la force de serrage ainsi que l'état des casques antibruit sont indiqués comme étant d'importantes variables de l'atténuation du bruit.

Lors de l'étude à la mine Lockerby, le niveau d'atténuation du bruit "NO NOISE" des casques antibruit était d'une moyenne d'environ 12,5 dBA avec un écart type d'environ 4 à 6 dBA suivant l'utilisation ISO ou OSHA.

Cependant, d'après les mesures de la force de serrage par rapport à celles de la taille de la tête, les casques antibruit Mark V qui ont remplacé les casques utilisés dans cette étude pourraient assurer une atténuation du bruit de >14 dBA.

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INTRODUCTION

As part of the ongoing program of abating noise pollution at all Falconbridge Mines measurements were taken to test the efficiency of ear muffs which were being used. Most of the analyses were done on "NO NOISE" ear muffs, model NN3-F because they were the ones used by 95% of the workforce.

The following ear muffs were tested at the Lockerby Mine:

1) "NO NOISE", model NN3-F, the Hellberg Standard Volume Hearing Protector, hard hat attachment;
2) Mark IV, MSA, worn behind the head;
3) Peltor H7P3e, hard hat attachment;
4) David Clark, model E-705, hard hat attachment;
5) Racal.

Forty-six tests of head size and clamping force, and 21 attenuation tests were performed on the "NO NOISE" ear muffs. On the Mark IV muffs 7 tests of attenuation were done, while only one such test was performed on each of the other brands.

The framework and method as well as theoretical and practical considerations are outlined in the main report which should be read to compare Lockerby results with other Falconbridge Mines.

Attenuation characteristics and noise reduction ratings (NRR) given in Table 1 are those which were supplied by manufacturers. From these manufacturers' ratings it appears that all muffs provide relatively equal attenuation.

MEASUREMENTS AND RESULTS

Tests were performed using Metrosonics instrument, type db-307. This instrument measures sound over the continuous range of 45 to 140 dBA. Its

Table 1 - Attenuation characteristics of ear muffs acquired for testing (ANSI S3.19-1974)

No.	Ear Muff	Characteristic	Frequency Hz									NNR
			125	250	500	1000	2000	3150	4000	6300	8000	
1	"NO NOISE" Model NN3-F Hellberg	Mean	16.2	19.9	25.2	34.1	36.0	39.2	39.0	40.3	38.1	24
		Std. Dev.	2.5	1.8	2.0	1.7	2.2	3.1	2.0	4.0	4.1	
2	Mark IV MSA	Mean	17.0	18.0	29.0	36.0	38.0	44.0	44.0	43.0	43.0	24
		Std. Dev.	2.6	2.6	3.1	3.2	4.1	7.2	4.6	4.7	5.7	
3	Peltor H7P3e	Mean	14.1	18.8	28.1	36.2	35.6	38.4	35.0	35.5	36.4	24
		Std. Dev.	2.1	2.0	3.0	2.1	2.2	2.3	2.1	2.1	2.4	
4	David Clark Model E-705	Mean	12.0	17.0	30.0	35.0	35.0	36.0	37.0	32.0	30.0	24
		Std. Dev.	2.5	3.0	4.6	5.6	4.5	4.3	4.2	4.1	2.9	
5	Racal	Mean	-	-	-	-	-	-	-	-	-	-
		Std. Dev.										

microprocessor continuously samples and displays dBA sound levels while calculating L_{max}, L_{peak} and test duration. Testing should be done using 4 dosimeters rather than 3, as we have done. This would simplify and speed up the testing time. It is very time-consuming and difficult to reset from OSHA (doubling at 5 dB) to ISO (doubling at 3 dB) in most work areas.

Cables and microphones should be small in size to avoid creating an opening that would cause leakage of sound at the point where they enter the muff (breaking the seal between muff and face). It was very difficult at times to position microphones comfortably inside ear muffs. Workers had a tendency to want to adjust their ear muffs while the test was being conducted, which sometimes caused leakage and forced us to repeat the test.

Conducting tests on workers using fixed equipment (such at ITH in-the-hole drills, jumbo drills, and diamond drills) were simpler to perform providing workers had no problems with their equipment and were willing to cooperate. Testing where workers use man-handling equipment, such as jack legs - stopers, scooptrams and mucking machines were more difficult.

The head size was measured with outside calipers, and clamping force with a manual balance.

HEAD SIZE AND CLAMPING FORCE

Head size and clamping force tests were performed on "NO NOISE" ear muffs, Mark IV muffs, David Clark muffs and Peltor muffs (Appendices A and B).

A symmetrical frequency, or bell-shaped curve was constructed on the basis of 64 head size tests (Figure 1). Previously, two frequency curves were constructed: a leptokurtic curve on the basis of a small population of 18 for attenuation tests; and a negatively skewed curve on the basis of a population of 46. Only on the basis of surveying a large population can precise results

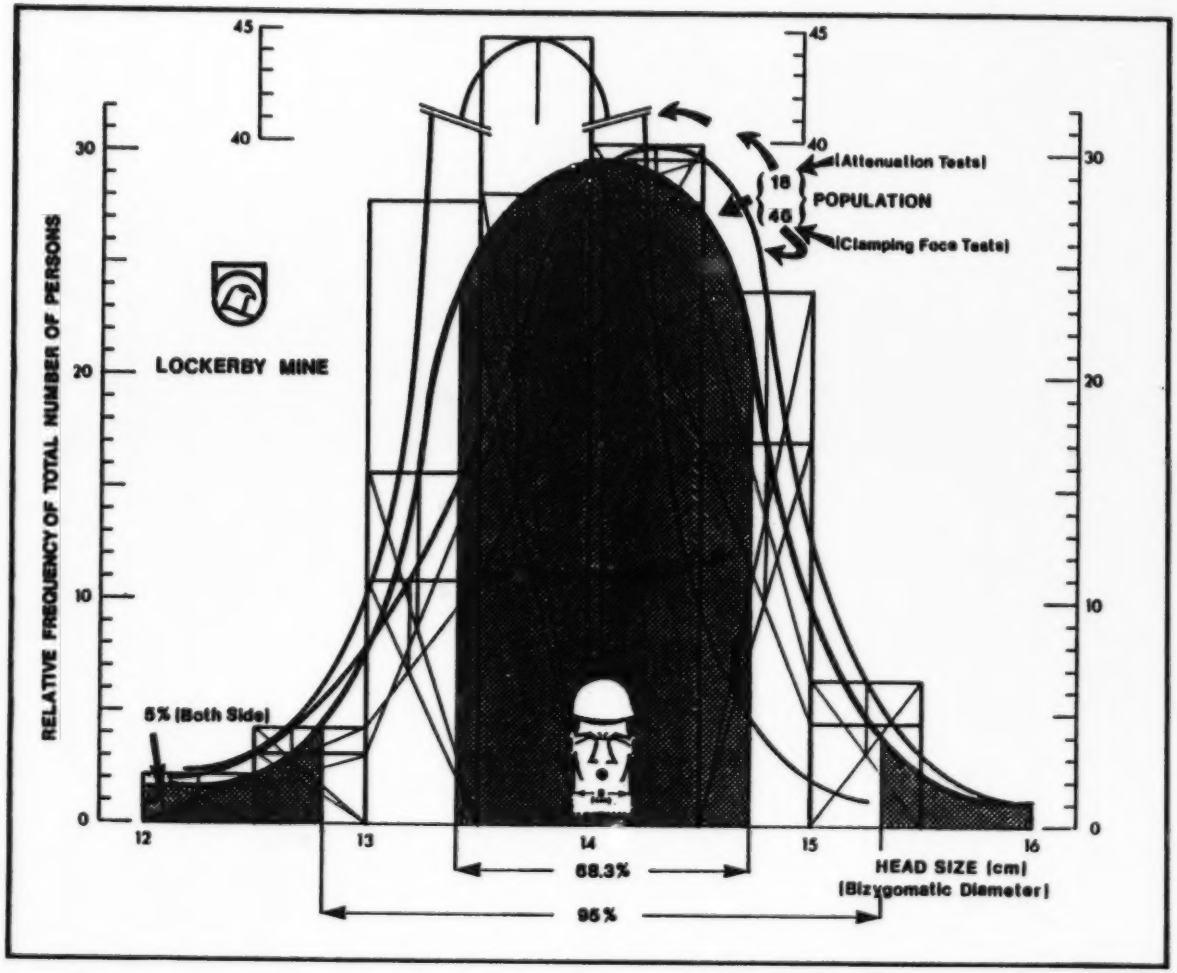

Fig. 1 - The symmetrical frequency or bell-shaped curve of head size tests (population 64).

be obtained. By simply calculating the above-mentioned curve nuances cannot be noticed (Table 2).

Table 2 - Summary of head size tests

No.	Test	N	Mean	Std. Dev.	Confidence Limit 90%	Confidence Limit 95%
1	Head size and clamping force "NO NOISE"	46	13.96	0.72	13.96±0.17	13.96±0.21
2	Head size and clamping force - different muffs	16	14.00	0.70	14.00±0.31	14.00+0.37
3	Attenuation	18	13.64	0.33	13.64±0.13	13.64±0.16
1-3	Σ	80	13.90	0.65	13.90±0.10	13.90±0.12

Population → Grand Mean

In this Table we can see that confidence limits are high, and that at Lockerby heads with normal bizygomatic diameters are prevalent (for North America the average head size is 14.35 cm).

A frequency curve was constructed from clamping force data (Figure 2). This bimodal frequency curve has two maxima: the first maximum at 600 (gwt) is related to a group with markedly small heads; the second maximum is at 1350 (gwt). From the clamping force versus population bar graph in Figure 2, relative symmetry is observable over the interval 900 to 1800 (gwt). Good attenuation would be expected in this range. To give substance to this assertation a bar graph was constructed from "NO NOISE" muff measurements of population -46 (Figure 3). The largest negative deviation, as well as the most rapid rate of ear muff deterioration, occurs for head sizes from 13.00 to 13.50 cm. Such is also the case at other mines. All other results are acceptable. Clamping force increases with head size.

Data from Appendix A was used to construct a standard deviation (error) ellipse (Figure 4). The ellipse largely covers the field of head size versus

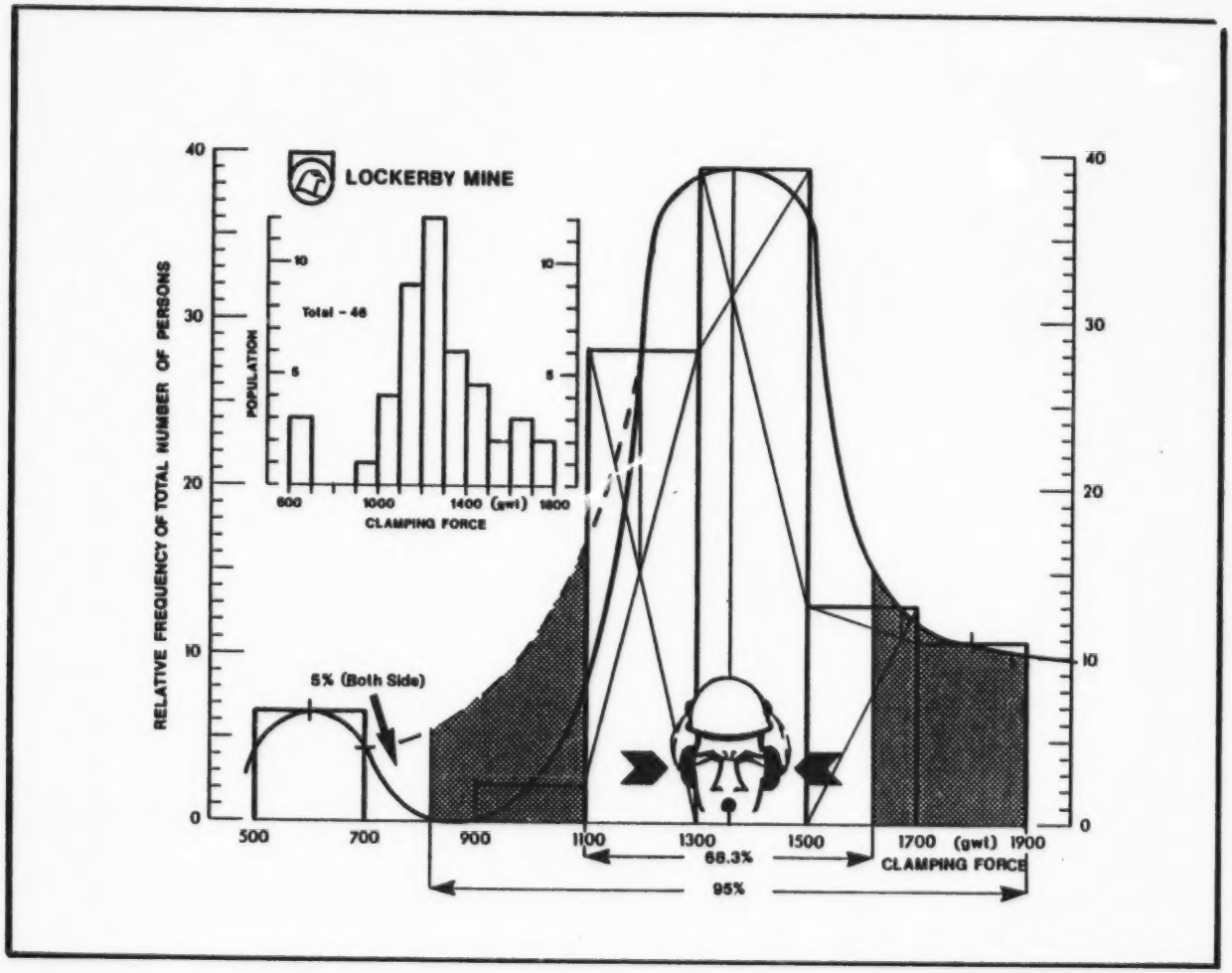

Fig. 2 - The bimodal frequency curve has two maxima: the first maximum is at 600 (gwt); and the second at 1350 (gwt).

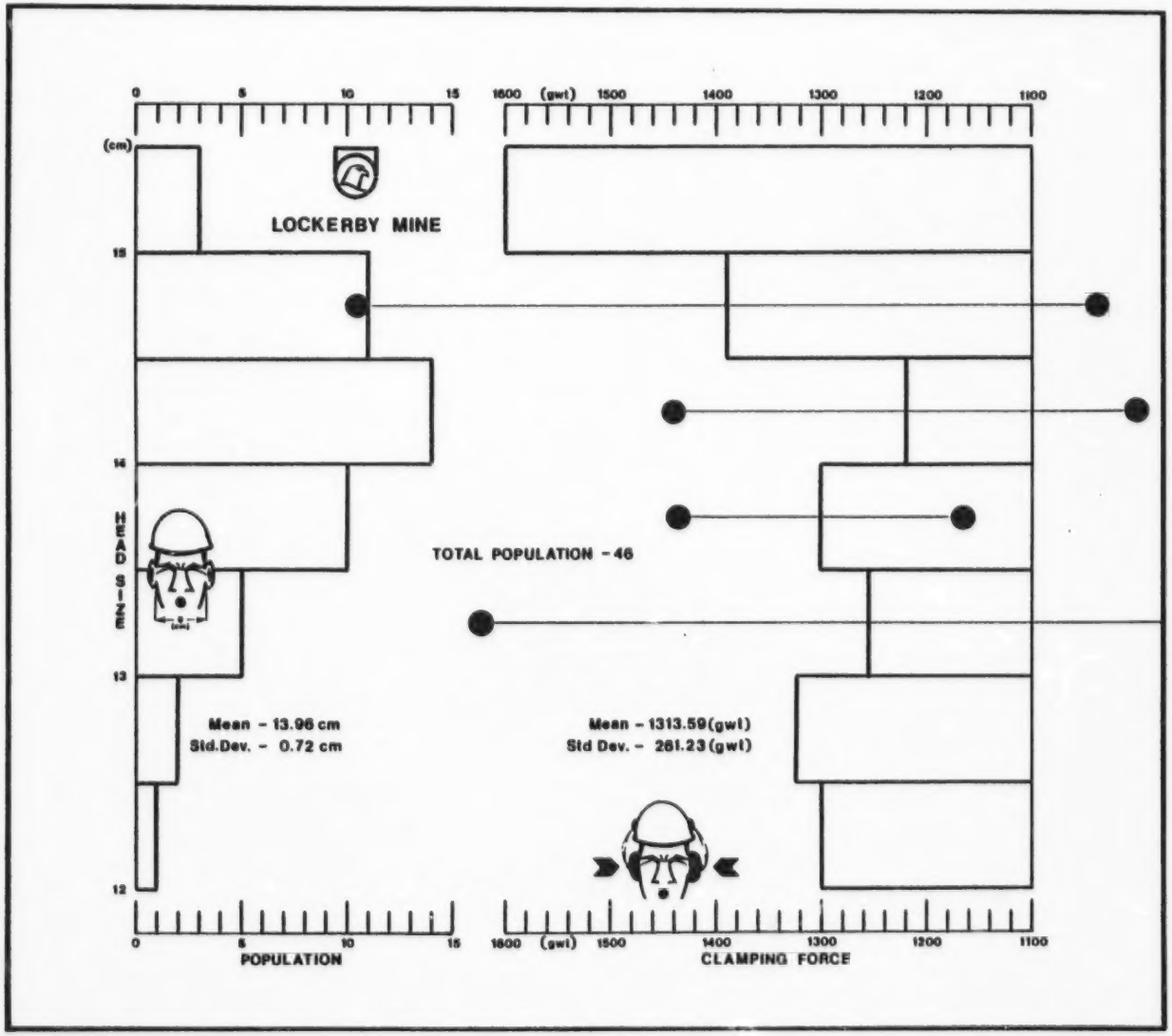

Fig. 3 - Relationships between head size and clamping force at the Lockerby Mine.

clamping force measured, and we can therefore expect good attenuation.

Utilization of OSHA prescribed methods of estimating the adequacy of hearing protector attenuation requires the availability of the manufacturer's published Noise Reduction Rating (NRR) and/or octave band attenuation data at frequencies ranging from 125 Hz to 8 kHz (1). This estimation method is the one which is used in all reports evaluating the Noise Exposure. We will compare NRR with our measurements to show the difference between estimated and actual values. Table 3 shows 30.6% of ear muff conditions were fair to poor. Nineteen percent of the ear muffs were in fair condition, while 11% were poor. We should expect attenuation to be poorer than rated.

Table 3 - Tests of ear muff conditions in the mine

No.	Ear Muff	N*	Ear Muff Conditions					
			Good		Fair		Poor	
			N_1	Percent	N_2	Percent	N_3	Percent
1	"NO NOISE" NN3-F	46	33	71.74	7	15.22	6	13.04
2	Mark IV MSA	13	8	61.54	4	33.77	1	7.92
3	David Clark, model E-705 Straightaway	2	2	100.00	0	0.00	0	0.00
4	Peltor H7P3e	1	0	0.0	1	100.00	0	0.00
1-4	Σ	62	43	69.35	12	19.35	7	11.29

Note: * Population ($N^* = N_1 + N_2 + N_3$)

While tests were being performed, ear muffs in fair to poor condition were maintained or replaced. Interestingly, ear muff clamping force was good overall at Lockerby, which was the last mine at which measurements were taken. Surveyors by then developed a routine, were more experienced and precise, and better evaluated ear muff conditions.

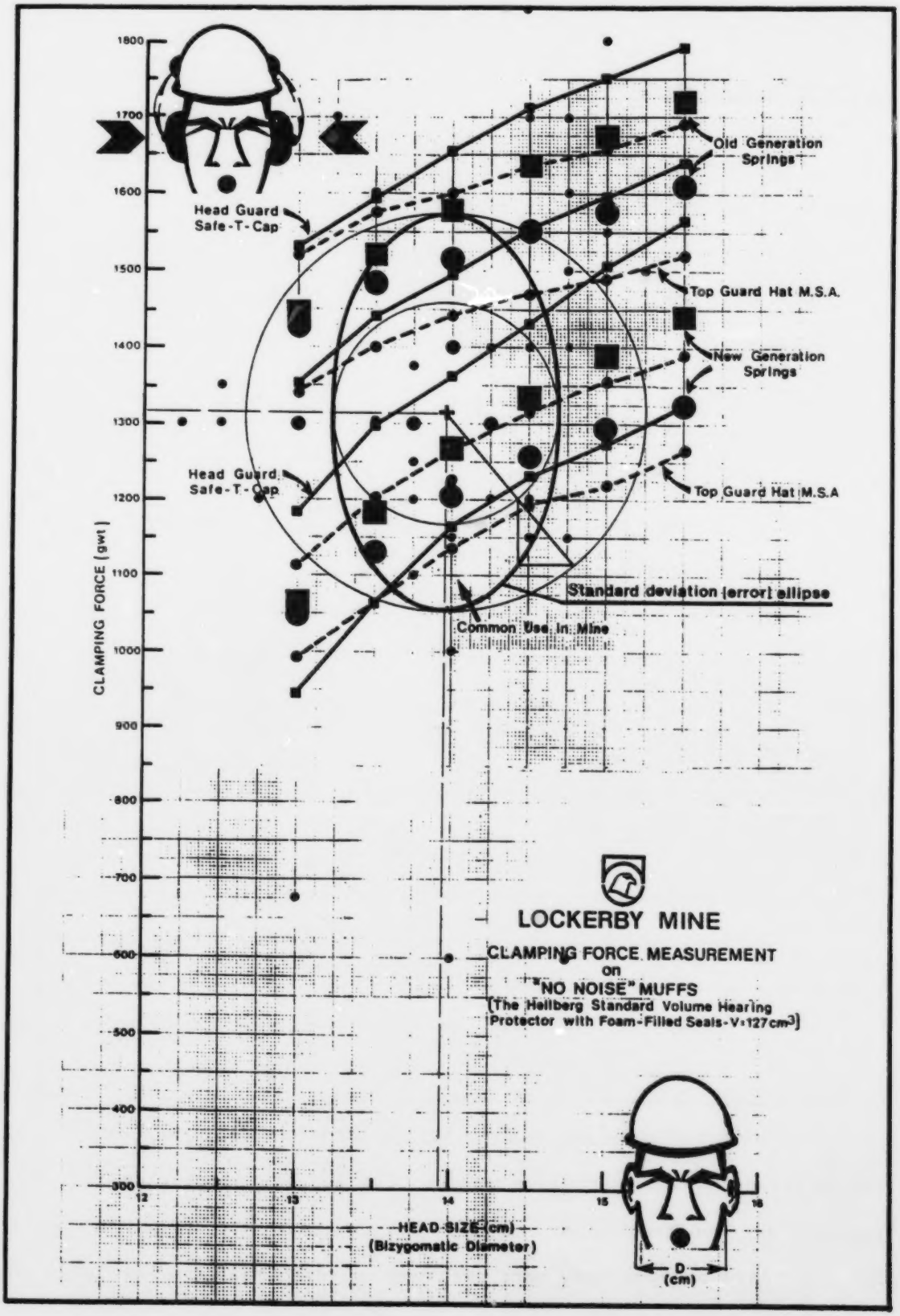

Fig. 4 - Standard deviation (error) ellipse of "NO NOISE" muffs.

ATTENUATION MEASUREMENTS

Attenuation measurements were performed on the following ear muffs:

1) "NO NOISE", model NN3-F, 10 measurements in OSHA mode (Appendix C) and 21 measurements in ISO mode (Appendix D);
2) Mark IV, MSA, 7 measurements in OSHA mode (Appendix C), and 7 measurements in ISO mode (Appendix E);
3) Peltor H7P3e, 1 measurement in ISO mode (Appendix E);
4) David Clark, model E-705, 1 measurement in OSHA mode (Appendix C), and 1 measurement in ISO mode (Appendix E);
5) Racal, 1 measurement in OSHA mode (Appendix C), and 1 measurement in ISO mode (Appendix E).

Testing was carried out at various types of equipment (e.g., Joy jack-legs and stopers, long-hole drills, in-the-hole ITH drills, diamond drills, slushers and scooptrams). A total of 19 tests in the OSHA mode, and 31 in the ISO mode were conducted.

Tests of "NO NOISE" ear muffs revealed the following attenuations (Appendices C and D):

Mode	dBA		Confidence Limit	
	Mean	Std. Dev.	90%	95%
OSHA	12.86	5.86	12.86±3.46 dBA	12.86±4.22 dBA
ISO	12.02	4.30	12.02±1.59 dBA	12.02±1.93 dBA

In both modes we get results which vary markedly. The most likely explanation of this variation in the OSHA mode is because of the small population. Results of other ear muffs are entered in the Appendices, but are not discussed because they were obtained on very small populations. The

reason for the small number of measurements is the lack of time for performing them, which was exacerbated by frequent instrument malfunctions.

At the Lockerby Mine almost 95% of the miners wear "NO NOISE" ear muffs, which have a smaller cup size. Workers with large ears find microphones in their muffs very annoying and claim that they cause an increase in noise levels. When positioning a microphone in the ear muff it is very important to take a noise reading (trial run) and readjust if necessary. Workers should be instructed not to adjust their muffs until the test has been completed. At times when a worker is working hard physically (lots of bending and reaching) in operating his equipment, adjustment is more frequent and more leakage occurs. Other muffs, such as Mark IV (Type 2), David Clark (Type 3), Peltor (Type 4), and Racal (Type 5), have a large cup, which should help avoid this problem. Indications are that measured attenuations of Types 2 to 5 muffs are poorer, as documented below:

N*	Mode	dBA		Confidence Limit	
		Mean	Std. Dev.	90%	95%
8	OSHA	9.96	7.31	9.96±4.60 dBA	9.96±6.07 dBA
10	ISO	10.96	8.22	10.86±4.91 dBA	10.86±5.92 dBA

Note: *Population

From these results it can be seen that the lower attenuation limit is too low at 5-6 dBA, while the higher limit is too high at 15-17 dBA according to the OSHA and EPA prescribed methods of estimating adequacy of hearing protector attenuation. This is because these ear muffs have the same NNR assigned as the "NO NOISE" muffs.

Comfort received better marks at Lockerby than in all the other Falconbridge mines. Only at Lockerby did comfort go hand in hand with clamping force. Comfort test results are given in Table 4.

Table 4 - Comfort of ear muffs in the mines

No.	Ear Muff	N*	○-Satisfactory		◒-Good		●-Very Good	
			N_1	Percent	N_2	Percent	N_3	Percent
1	"NO NOISE" NN3-F	23	11	47.8	7	30.4	5	21.7
2	Mark IV MSA	6	0	0.0	6	100.0	0	0.0
3	Peltor H7P3e	1	0	0.0	0	0.0	1	100.0
4	David Clark Model E-705	2	1	50.0	1	50.0	0	0.0
5	Racal	1	1	100.0	0	0.0	0	0.0
1-5	Σ	33	13	39.4	14	42.4	6	18.2

Note: * Population ($N^* = N_1 + N_2 + N_3$)

From these results it can be concluded that 60.6% of the workers deemed comfort to be good to very good. The cause of the positive clamping force/comfort relationship could not be found.

Using data from Appendices C, D and E, and Fraser Mine measurements, L_{max} and L_{peak} levels were calculated and were then compared with measurement results at Falconbridge and Strathcona Mines (Table 5). Measurements at Falconbridge and Strathcona were carried out with an integrating sound level meter, B and K, type 2225, whereas measurements at Fraser and Lockerby Mines were taken with a Metrosonics db-307 instrument. Instrument control was done to find means of standard deviations of L_{max} and L_{peak} (accuracy of instrument field test).

The results should be approximately the same, however, Lockerby and Fraser Mines' results differ considerably by 7 dBA. Calculating the L_{peak} from these measurements and drawing conclusions based on them would be inadvisable.

Table 5 - Peak levels in mining operations at the Falconbridge mines.

Falconbridge - Strathcona Instrument: Bruel and Kjaer Integrating Sound Level Meter Type 2225.							Fraser - Lockerby Instrument: Metrosonics db-307 Noise Dosimeter and Integrating Sound Level Meter.				
No.	Sound Source	dBA L_{max} Mean Std. Dev.	dBA L_{peak} Mean Std. Dev.	Δ	N		dBA L_{max} Mean Std. Dev.	dBA L_{peak} Mean Std. Dev.	Δ	N	Comments
1	Jack Leg Drill	118.65 3.36	134.85 5.68	16.3	11		121.43 2.35	148.0 0.0	26.6	9	In $Mean_{SD}$, value not included
2	Stoper Drill - Rock Bolter	118.51 5.92	135.0 7.0	16.5	22		118.48 1.65	141.92 6.22	23.4	18	
3	Jumbo Drill - two booms	116.96 5.91	122.14 5.91	15.19	8		109.02 1.03	136.85 10.47	27.8	15	
4	Long Hole Drill	119.19 1.98	135.08 2.59	15.89	4		116.06 2.79	141.12 6.87	25.06	5	
5	Long Tom Drill - two booms	120.27 2.99	137.17 4.63	16.9	23		-	-	-	-	
6	ITH In the Hole Drill	98.27 5.12	116.25 5.66	17.98	7		101.06 5.79	121.65 18.36	20.59	37	
7	Diamond Drill	104.02 4.76	120.81 9.93	16.79	7		108.6 1.77	133.74 11.90	25.14	18	
8	Mucking Machine	106.58 3.60	121.53 3.53	14.95	4		109.97 0.51	147.26 1.18	37.29	5	
9	Bolting Machine	-	-	-	-		110.55	147.0	36.4	1	
10	Air Plugger (Brk. Cement)	-	-	-	-		112.20 0.57	148.0 0.0	35.8	2	In $Mean_{SD}$, value not included
11	Slusher	97.50 4.99	111.35 4.45	13.85	4		115.30 1.27	148.0 0.0	32.7	2	In $Mean_{SD}$, value not included
12	Scooptram	106.55 14.57	123.33 11.80	16.78	12		108.18 5.22	142.12 9.38	33.94	16	
13	Conveyor Man	94.83 6.40	112.15 8.35	17.32	3		-	-	-	-	
14	Chute Puller	114.80 9.19	133.15 3.32	18.35	2		-	-	-	-	
15	Vent. Fan - 38" 60 HP	-	-	-	-		100.48 5.10	117.91 14.12	17.43	4	
16	Primary Crusher - U/G Jaw Crush.	102.34 6.93	121.56 8.24	19.22	8						
17	Secondary Crusher	91.77 1.33	106.27 1.62	14.5	3						
18	Tertiary Crusher	95.45 0.21	108.35 0.64	12.9	2						
19	Ball Mill	93.20 2.02	107.57 1.16	14.37	3						
20	Flotation Op. Area	85.9	99.3	13.4	1						
21	Compressor Room	89.7	103.0	13.3	1						
22	Power House	94.5	107.5	13.0	1						
23	Electrostatic Precipitator	93.65 0.35	109.20 3.82	15.55	2						
24	Converter Puncher	99.13 1.10	114.27 1.79	15.14	3						
25	Converter Skimmer - Fluxing	89.47 4.76	103.83 4.91	14.36	3						

	$Mean_{SD}$ Std.Dev.	$Mean_{SD}$ Std.Dev.	
	4.51	5.00	
◇19	3.45	3.04	19◇

	$Mean_{SD}$ Std.Dev.	$Mean_{SD}$ Std.Dev.	
	2.98	9.81	
◇8	2.09	5.25	8◇

Laboratory tests of instrument accuracy done at Laval University came to the same conclusion (2). This was the reason why L_{max} and L_{peak} measurements at Fraser and Lockerby were not presented in the main report prepared for Falconbridge Ltd.

CONCLUSION

Measurements have shown that the attenuation of "NO NOISE" ear muffs was about 12.5 dBA. Ear muff efficiency is dependent on the frequency range of noise. Overall, the condition of ear muffs was satisfactory, but it should be noted that 11% of the ear muffs were in poor shape (Table 3). The safety department must continue to work diligently in maintaining and replacing ear muffs while the workers continue to be properly trained in correctly fitting ear muffs. Head shapes and sizes had a marked effect on attenuation, as did physical obstructions (e.g., eye glasses, ear size) that weaken attenuation. From the data we can conclude that ear muffs in themselves are not a complete solution to the attenuation of the noise level in the mining environment.

Ear muff control should be continued by measuring head size and clamping force with the apparatus suggested in the main report for better attenuation.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the help and cooperation of E. Isaacs, Director, and P. Savalas, Field Technicial of M.A.P.A.O, as well as the Senior Mine Supervisor, T. Lakanen, Lockerby Mine, and Dr. A.G. Cecutti, Medical Director, D. McPhee, and R. Desjardins, Technician, Falconbridge Ltd.

Acknowledgement is also extended to J. Vergunst, Working Environment Engineer, Ontario Ministry of Labour, Sudbury, and R. Pleasance, Branch Manager, Levitt-Safety Ltd. (Metrosonics Inc.), Sudbury, Ontario for the loan

of the instruments.

Thanks are extended to G. Knight, Research Scientist, Elliot Lake Laboratory, for reviewing the manuscript and making numerous helpful suggestions.

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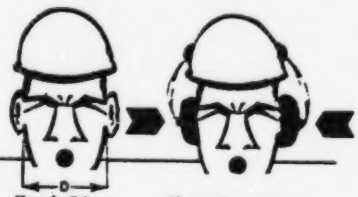
1. EPA, "Noise labeling requirements for hearing protectors"; Fed Regist 42(190), 40 CFR Part 211, 56139-56147; 1979.

2. Archambault, R., Private communication; 1985.

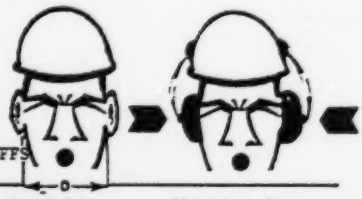
Head size and clamping force data of "NO NOISE", model NN3-F ear muffs.



No.	Occupation	Condition	Head Size (cm)	Clamping Force (gwt)
1	Driller	2	14.00	1150
2	Driller	1	14.00	1000
3	Driller	1	14.25	1300
4	Driller	1	12.75	1200
5	Driller	2	14.00	1400
6	Driller	1	15.00	1800
7	Driller	1	13.00	1300
8	Driller	1	13.00	1300
9	Driller	1	14.50	1250
10	Driller	1	13.00	675
11	ITH Driller	1	12.50	1350
12	ITH Driller	1	14.75	1150
13	ITH Driller	1	14.75	1500
14	Drift Leader	1	15.00	1500
15	Drift Leader	1	14.00	1200
16	Drift Leader	1	14.75	1600
17	Drift Leader	1	14.50	1150
18	Longhole Driller	1	14.00	1500
19	Spare Man	1	14.00	1400
20	Spare Man	1	13.50	1400
21	Blaster's Helper	3	14.75	600
22	Chute Blaster	1	14.25	1300
23	Motorman	3	14.00	600
24	Trammer	3	12.50	1300
25	Scooptram	1	12.25	1300
26	Scooptram	1	13.75	1300
27	Scooptram	2	13.00	1300
28	Scooptram	2	13.75	1200
29	Scooptram	1	14.75	1700
30	Scooptram	1	14.50	1850
31	Scooptram	1	13.75	1100
32	Scooptram	2	14.00	1200
33	Mechanic	1	14.50	1400
34	Mechanic	1	14.25	1400
35	Mechanic	3	13.75	1300
36	Mechanic	1	14.00	1200
37	Mechanic	3	14.00	1225
38	Mechanic	2	14.75	1400
39	Mechanic	1	13.75	1250
40	Mechanic	2	14.50	1700
41	Electrician	1	13.50	1600
42	Level Cleaner	1	15.25	1500
43	Level Cleaner	3	13.25	1700
44	Level Cleaner	1	13.50	1300
45	Level Cleaner	1	13.75	1375
46	Shift Boss	1	14.25	1200
	Mean:		13.96	1313.59
	Std. Dev.:		0.72	261.23

Note: 1 - Good; 2 - Fair; 3 - Poor.

Head size and clamping force data of different muffs:
Mark IV, MSA; David Clark, Model E-705; Straightaway; and Peltor H7P3e



No.	Occupation	Condition	Head Size (cm)	Clamping Force (gwt)
1	Driller	1	13.75	1700
2	Driller	2	13.50	1700
3	Driller	2	13.00	1450
4	Driller	2	15.00	1100
5	Driller	1	13.75	1500
6	Driller	1	14.50	1550
7	Drift Leader	1	14.50	1200
8	Drift Leader	1	14.25	1000
9	Raise Leader	1	14.00	1200
10	Raise Leader	1	14.00	1200
11	Cage Tender	2	15.00	1000
12	Cage Tender	1	15.25	1525
13	Cage Tender	3	14.50	550
	Mean:		14.25	1313.46
	Std. Dev.:		0.65	339.82

DAVID CLARKE MUFFS

No.	Occupation	Condition	Head Size (cm)	Clamping Force (gwt)
1	Level Cleaner	1	14.00	500
2	Vent. Foreman	1	14.00	1400

PELTOR (H7)

No.	Occupation	Condition	Head Size (cm)	Clamping Force (gwt)
1	Electrician	2	13.00	600
	Mean:		14.00	1290.32
	Std. Dev.:		0.70	303.04

Note: 1 - Good; 2 - Fair; 3 - Poor.

Attenuation tests of "NO NOISE" model NN3-F; Mark IV, MSA; David Clark, model E-705; and Racal ear muffs in the OSHA mode.

No.	Equipment	Comfort	L. Avg. (dBA)	Attenuation (dBA) L.S.	R.S.	B.S.	L. Max (dBA)	Attenuation (dBA) L.S.	R.S.	B.S.	L. Peak (dBA)	Attenuation (dBA) L.S.	R.S.	B.S.	Comments	Location
							EAR MUFF - "NO NOISE"									
1	2 Jack Leg Drill AL-60	○	11.25	119.0	15.3	12.5	13.9	124.5	17.1	13.4	15.3	148.0	9.8	9.0	9.4	Both arms bent	3100 Level
2	2 Jack Leg Drill AL-60	○	-	118.7	12.1	9.6	10.8	120.9	6.2	8.1	7.2	148.0	12.3	13.4	12.9		1700 Level
3	Long Hole Drill	○	13.25	104.9	3.0	2.1	2.5	114.7	5.5	5.1	5.3	147.8	14.7	15.1	14.9	Adjust. screw missing on muffs	1800 Level
4	ITH-In the Hole Drill	○	13.75	114.8	5.5	18.3	11.9	118.9	11.8	19.2	15.5	148.0	17.4	24.2	20.8	Left arm on muff bent	3100 Level
5	ITH-In the Hole Drill	◒	14.0	101.8	23.8	23.3	23.5	103.1	7.6	11.2	8.9	148.0	4.9	23.3	14.1		3100 Level
6	Diamond Driller	◒	13.75	103.2	9.7	19.7	14.7	107.3	11.2	19.2	15.2	145.8	22.5	19.0	20.8	Left arm on muff bent	1700 Level
7	Diamond Driller-Helper	○	13.50	104.4	19.8	16.6	18.2	107.8	20.0	17.0	18.5	148.0	27.4	25.0	26.2		1700 Level
8	Air Slusher	○	13.25	110.7	23.6	8.2	15.9	114.4	22.4	10.7	16.5	148.0	27.5	25.2	26.4		3100 Level
9	Scooptram ST5	○	14.0	102.9	5.4	8.7	7.0	108.6	4.1	5.7	4.9	148.0	24.5	16.0	20.2	Adjust. screw missing on muffs	1800 Level
10	Scooptram JS500	○	-	98.6	10.2	10.2	10.2	114.8	19.4	18.6	19.0	148.0	17.6	6.4	12.0		3400 Level
	Mean		13.59	107.9	12.84	12.92	12.86	113.50	12.53	12.72	12.63	147.75	17.86	17.65	17.77		
	Std. Dev.		0.33	7.36	7.56	6.41	5.86	6.77	6.74	5.54	5.47	0.69	7.61	6.80	5.95		
							EAR MUFF - MARK IV									
1	2 Jack Leg Drill AL-60	-	13.5	116.0	6.1	10.2	8.1	122.8	7.2	10.9	9.0	148.0	6.5	8.7	7.6		3100 Level
2	2 Jay Stopers-Rock Bltg.	○	13.0	110.2	1.5	3.3	2.4	119.2	9.0	4.9	6.9	148.0	10.6	12.4	11.5	Cushions bad shape, not worn	1800 Level
3	Stoper Driller-Rock Bltg	○	-	108.0	13.1	11.1	12.1	118.8	14.7	11.9	13.3	148.0	22.0	15.9	19.0	Muffs not adjusted properly	-
4	ITH-In the Hole Drill	○	13.75	102.8	9.0	8.5	8.7	103.7	7.0	7.8	7.4	148.0	27.5	28.0	27.8	Left arm on muff bent	3700 Level
5	ITH-In the Hole Drill	○	13.75	100.3	23.0	23.6	23.3	103.2	17.9	13.9	15.9	148.0	20.1	28.0	24.0		3100 Level
6	Diamond Driller	○	14.00	102.9	3.1	14.3	8.7	107.6	6.3	12.1	9.2	148.0	28.0	28.0	28.0	Cushions bad shape, bent arms	1700 Level
7	Scooptram ST2	○	13.50	97.5*	+2.1*	+1.0*	+1.5*	108.1*	3.1*	+0.8*	1.15*	148.0*	15.4*	11.8*	13.6*	Cushions bad shape, not worn	2600 Level
	Mean		13.58	106.70	9.30	11.83	10.55	112.55	10.35	10.25	10.28	148.0	19.12	20.17	19.65		
	Std. Dev.		0.34	5.85	7.90	6.81	6.99	8.70	4.80	3.30	3.56	0.0	8.83	8.88	8.57		
							EAR MUFF - DAVID CLARK									
1	Diamond Driller	○	14.0	106.2	19.9	12.2	16.0	108.4	18.9	9.3	14.1	148.0	28.0	28.0	28.0	Right arm on muff bent	1700 Level
							SAFETY MUFFS - RASCAL									
1	Scooptram ST500 (Rem.Con)	○	14.25	96.8	0.2	0.6	0.4	110.9	4.2	1.1	2.6	148.0	15.2	15.4	15.3	No adjustment on left	3100 Level

Note: ○ Satisfactory; ◒ Good; ● Very Good.

* In mean value not included.

Attenuation tests of "NO NOISE" model NN3-F in the ISO mode

No.	Equipment	Comfort		L Avg. (dBA)	Attenuation (dBA) L.S.	R.S.	B.S.	L Max (dBA)	Attenuation (dBA) L.S.	R.S.	B.S.	L Peak (dBA)	Attenuation (dBA) L.S.	R.S.	B.S.	Comments	Location
1	Jack Leg Drill AL-60	○	-	116.7	12.0	14.6	13.3	118.8	9.7	13.3	11.5	148.0	16.0	17.7	16.9		-
2	Stoper Drill-Rock Bltg.	●	-	116.7	18.5	20.3	19.4	120.2	18.6	21.1	19.9	136.8	13.2	13.5	13.4		3100 Level
3	Stoper Drill-Rock Bltg.	●	-	113.0	16.3	1.2	8.7	120.1	0.4	15.5	7.9	139.5	11.8	11.6	11.7		3300 Level
4	Long Hole Drill	○	13.25	111.5	9.6	12.2	10.9	115.5	7.1	16.9	12.0	148.0	16.4	22.9	19.7	Adjust. screw missing on muffs	1800 Level
5	Long Hole Drill	○	13.5	118.7	16.1	18.7	17.4	118.7	10.4	17.9	14.1	140.3	16.3	11.6	13.9	Left arm on muff bent	3100 Level
6	Long Hole Drill	◒	-	112.4	14.9	18.2	16.5	112.4	16.0	16.3	16.15	132.0	9.2	11.6	10.4		3300 Level
7	Long Hole Drill	◒	-	119.0	6.2	7.3	6.7	119.0	2.4	[illegible].9	4.1	137.5	2.0	2.2	2.1		3300 Level
8	ITH-In the Hole Drill	◒	13.5	101.9	16.6	20.0	18.3	102.3	16.[illegible]	[illegible].8	16.1	148.0	27.8	26.3	27.1		3100 Level
9	ITH-In the Hole Drill	●	-	98.3	17.1	7.9	12.5	102.8	20.[illegible]	7.9	14.4	123.1	5.6	0.5	1.1		1875 Level
10	ITH-In the Hole Drill	●	-	96.9	10.1	13.0	11.5	98.7	4.1	13.7	7.4	120.0	0.0	1.5	0.75		1875 Level
11	ITH-In the Hole Drill	●	-	96.0	12.9	22.6	17.75	98.5	9.0	20.0	14.5	120.0	0.0	0.9	0.45		1875 Level
12	ITH-In the Hole Drill	◒	-	95.2	5.8	5.9	5.85	98.4	4.6	4.3	4.45	121.4	2.8	0.0	1.4		2000 Level
13	ITH-In the Hole Drill	○	-	105.2	10.3	12.5	11.4	108.8	7.8	9.6	8.7	129.3	3.7	0.8	2.25		2000 Level
14	ITH-In the Hole Drill	◒	-	99.1	9.0	7.7	8.4	100.7	6.8	5.5	6.2	121.6	1.9	1.2	1.5		3100 Level
15	ITH-In the Hole Drill	○	-	96.7	7.6	8.2	7.9	98.3	[illegible].6	6.5	5.7	121.[illegible]	0.5	0.3	0.4		3100 Level
16	Diamond Driller	◒	13.75	101.8	17.7	1.4	9.5	107	18.3	6.7	12.[illegible]	[illegible]45.0	28.0	26.9	27.45	Left arm on muff bent	1700 Level
17	Diamond Driller Helper	○	13.5	107.1	16.4	19.5	17.9	109.0	13.6	9.0	12.3	[illegible]35.0	2.0	23.4	12.7		1700 Level
18	Air Slusher	○	13.25	112.1	7.6	5.3	6.4	116.2	9.1	6.2	7.7	148.0	2[illegible].0	22.0	22.5		3100 Level
19	Scooptram ST5	○	14.0	105.0	9.5	8.2	8.8	109.0	2.7	4.5	3.6	148.0	16.7	17.2	17.0		2400 Level
20	Scooptram JS500	○	-	99.9	11.1	11.3	11.2	116.4	21.9	14.5	18.2	148.0	21.6	12.1	16.9		3400 Level
21	Scooptram JS560	○	-	104.0	9.0	15.3	12.1	114.6	12.2	11.7	11.95	133.0	0.4	35.7	18.0		3100 Level
	Mean		13.54	106.06	12.11	11.97	12.02	109.94	10.41	11.42	10.92	135.55	10.42	12.90	11.41		
	Std. Dev.		0.27	8.02	4.08	6.33	4.30	8.22	6.45	5.35	4.19	11.02	9.50	11.70	9.04		

Note: ○ Satisfactory; ◒ Good; ● Very Good.

Attenuation tests of Mark IV, MSA; David Clark, model E-705; and Racal muffs in the ISO mode

No.	Equipment	Comfort		L Avg. (dBA)	Attenuation (dBA) L.S.	R.S.	B.S.	L Max. (dBA)	Attenuation (dBA) L.S.	R.S.	B.S.	L Peak (dBA)	Attenuation (dBA) L.S.	R.S.	B.S.	Comments	Location
									EAR MUFF - MARK IV								
1	2 Jack Leg Drills AL-60	-	13.5	118.7	12.4	8.4	10.4	124.0	3.2	8.3	10.8	148.0	9.3	9.4	9.35		3100 Level
2	Stoper Dr.-Rock Bltg.	○	-	110.8	15.3	5.4	10.3	117.5	13.1	6.4	9.7	148.0	16.0	13.0	14.50	Claims muffs not adjusted	3100 Level
3	2 Jay Stopers-Rock Bltg	○	13.0	114.0	4.9	0.5	2.7	119.7	5.8	5.2	5.0	147.8	12.8	13.3	13.1	Cushions bad shape, not worn	1800 Level
4	ITH-In the Hole Drill	○	13.75	97.7	6.1	8.4	7.2	101.5	7.3	9.7	8.5	148.0	28.0	28.0	28.0	left arm on muff bent	3100 Level
5	ITH-In the Hole Drill	○	13.75	102.0	17.5	25.7	21.6	103.2	16.1	18.3	17.2	134.0	0.0	28.0	14.0		3100 Level
6	Diamond Driller	○	14.00	104.8	8.3	5.2	6.7	107.9	6.7	7.6	7.2	148.0	27.7	28.0	27.9	Cushions bad shape (bent arms)	1700 Level
7	Scooptram ST2	○	13.25	102.9	4.8	2.2	3.5	108.2	3.9	1.0	2.5	148.0	17.1	15.2	16.2	Cushions bad shape, not worn	2600 Level
	Mean		13.54	107.27	9.90	7.97	8.91	111.71	9.44	7.93	8.70	145.97	15.84	19.27	17.58		
	Std. Dev.		0.37	2.45	5.18	8.35	6.14	8.68	4.62	5.40	4.69	5.28	9.49	8.14	7.38		
									EAR MUFF - M.S.A. PELTOR (H7)								
1	Stoper Dr.-Rock Bltg.	●	-	115.4	28.7	25.2	26.9	120.5	27.1	24.8	26.0	138.5	13.8	15.6	14.7		3300 Level
									EAR MUFF - DAVID CLARK								
1	Diamond Driller-Help.	◒	14	105.2	21.1	9.0	16.0	108.9	23.6	9.2	16.4	148.0	28.0	23.7	25.9	Right arm on muff bent	1700 Level
									SAFETY MUFFS - RASCAL								
1	Scooptram ST500 (Rem.Con)	○	14.25	100.4	6.3	3.0	3.3	114.4	11.4	11.7	11.5	148.0	17.3	17.3	17.3	No left adjustment	3300 Level

Note: ○ Satisfactory; ◒ Good; ● Very Good.